AMALGAM BONDING

Disadvantages of amalgam include microleakage (Wing & Lyell, 1966; Going, 1979; Andrews & Hembree, 1980; Ben-Amar, 1989) and lack of adhesion to tooth structure (Lacy & Staninec, 1989; Charlton, Murchison & Moore, 1991; DeSchepper & others, 1991; Bagley, Wakefield & Robbins, 1994; Newman, Hondrum & Clem, 1996). To a great extent, amalgam bonding was developed to address these concerns.

Bonding amalgam to teeth was first suggested in 1983 when polyacrylic acid, oxide, and silver was used as the adhesive agent (Zardiackas & Stoner, 1983). Current bonding techniques were described in the mid- to late-1980s.

Definition of Amalgam Bonding: the use of an adhesive, usually a dentin bonding agent or resin cement, as a varnish substitute to bond amalgam to tooth structure.

Three Main Purported Advantages of Amalgam Bonding

1. Increase retention of amalgam restoration
2. Reduce or prevent post-placement leakage
3. Reduce or prevent post-placement sensitivity

It is also claimed that bonding amalgam to tooth structure will reinforce remaining tooth structure (ie, lone-standing cusps).

Procedure has become very popular in recent years:

--described by Gordon Christensen as "state-of-the-art" procedure (Christensen, 1994a; Christensen 1994b)

--taught as standard procedure when placing amalgams at some dental schools

Amalgam bonding has become popular because: *in vitro* studies have demonstrated its advantages, advertising promotes it, and products have been marketed specifically as amalgam bonding agents (eg, Amalgambond, [Parkell], Amalcoden [Mion]).

Amalgam Bonding Procedure

The procedure itself is often the same one used when the bonding product is placed to bond resin composite to tooth structure.

Three steps are involved:

1. Application of an acid to enamel and dentin (acid etching)
2. Application of a hydrophilic monomer in a volatile solvent (priming)
3. Application of an unfilled or partially filled resin

(sealing)

The current consensus is that amalgam bonding products bond amalgam to tooth structure by forming a micromechanical bond to the underlying dentin and enamel and to the overlying amalgam (Eakle, Staninec & Lacy, 1992; Miller & others, 1992; Eakle & others, 1994). Some chemical bonding may occur between the amalgam and adhesive, but it probably contributes little to the overall strength of the bond (Eakle & others, 1994; Ruzickova, Staninec & Marshall, 1994).

Manufacturers of the first "amalgam bonding products" provided products that had chemically-cured (or at least dual-cured) adhesive resins so the amalgam could mechanically interlock with the adhesive during amalgam condensation and setting. Today, however, the adhesive resins used for amalgam bonding are light activated before the amalgam is placed. The rationale is that the thin air-inhibited layer of the adhesive polymerizes when covered by the amalgam (Vargas, Denehy & Ratananakin, 1994). This is purported to be sufficient to retain the amalgam.

Although one well-known product is marketed exclusively for amalgam bonding (Amalgambond [Parkell]), most of today s current-generation dentin bonding agents come with instructions that describe their use for amalgam bonding. Examples include OptiBond (Kerr), Scotchbond Multi-Purpose Plus Adhesive (3M ESPE), All-Bond 2 (Bisco), and Prime & Bond NT (Dentsply/Caulk). In addition, resin cements such as Panavia 21 (J. Morita) and RelyX ARC (3M ESPE) can also be used.

Because amalgam bonding is purported to bond amalgam to teeth, reduce leakage, and reduce post-placement sensitivity, evidence should be examined to determine if these claims are true.

First Claim: Bonding Amalgam to Tooth Structure

Many laboratory studies indicate that amalgam bonding products do bond amalgam to tooth structure (DeSchepper & others, 1991; Kawakami & Staninec, 1992; Silva e Souza & others, 1993; McComb, Brown & Forman, 1995; Hollis & others, 1996; Ratananakin, Denehy & Vargas, 1996). The mechanism is a micromechanical one in which the bonding agent adheres to tooth structure and interlocks with the hardening amalgam (Eakle & others, 1992; Gendusa, 1992; Miller & others, 1992; Temple-Smithson, Causton & Marshall, 1992; Eakle & others, 1994; Vargas & others, 1994). Scanning electron microscopy has confirmed this mechanism (Scherer & others, 1992; Ruzickova & others, 1994; McComb & others, 1995). Results vary from product to product and are affected by application technique and study design, but a measurable bond can be recorded under *in*

vitro conditions (Varga, Matsumura & Masuhara, 1986; Staninec & Holt, 1988; Staninec, 1989; Covey & Moon, 1991; DeSchepper & others, 1991; Charlton, Moore & Swartz, 1992; Hasegawa & others, 1992; Staninec & others, 1992; Al-Moayad, Aboush Ye & Elderton, 1993; Ianzano, Mastrodomenico & Gwinnett, 1993; Silva E Souza & others, 1993; Eakle & others, 1994; Vargas & others, 1994; Cobb & Diefenderfer, 1996; Winkler & others, 1996; Winkler & others, 2000). The bond of amalgam to tooth structure is weaker than the bond of resin composite to tooth structure (Cooley, Tseng & Barkmeier, 1991; Miller & others, 1992; Nakabayashi, Watanabe & Gendusa 1992). In fact, even at their strongest, maximum values for amalgam bonding are only 1/3 the values commonly seen when the same products are used for resin composite bonding (DeSchepper & others, 1991; Kawakami & Staninec, 1992). The key question is whether or not the bond strength is high enough to be contribute to long-term clinical success.

Researchers have also studied the possible reinforcement of remaining cusps when amalgam is bonded to them. First discussed in 1976, the theory is that amalgam bonding may increase the fracture resistance of lone-standing or weakened cusps (Denehy & Torney, 1976). The majority of studies indicate that, at least in the immediate post-restoration period, amalgam bonding does make remaining tooth structure more resistant to cuspal deflection or to fracture than if no bonding had been used (Christensen & others, 1991; Eackle & others, 1992; Boyer & Roth, 1994; Borchert & Boyer, 1996; El-Badrawy, 1996; Pilo, Brosh & Chweidan, 1998; El-Badrawy, 1999). The reinforcement appears to be especially effective when a bonding agent is used in conjunction with horizontal pins (Uyehara, Davis & Overton, 1999). Although at least one article showed no deterioration in the protection offered by bonding (El-Badrawy, 1999), many articles have found that the reinforcement effect deteriorates over time (McComb & others, 1995; Bonilla & White, 1996; Oliveira, Cochran & Moore, 1996). Theories to explain this deterioration have included partial or complete debonding due to expansion/contraction from temperature changes (Santos & Meiers, 1994), or the result of exposure to moisture (Bonilla and White, 1996) and/or occlusal loading (McComb & others, 1995).

Second Claim: Reducing or Preventing Leakage

A significant problem associated with amalgam is post-placement microleakage (Wing & Lyell, 1966; Smith, Wilson & Combe, 1978; Yu, Wei & Xu, 1987; Ben-Amar, 1989). All types of amalgam leak, however single-composition-spherical alloys have been shown to exhibit more leakage that other types because their particles don t adapt intimately to the walls and floor of the cavity preparation. Leakage can lead to sensitivity (Newman, 1984),

marginal staining, recurrent caries, pulpitis, and even necrosis (Going, 1972; Bergenholtz & others, 1982; Saiku, St Germain & Meiers, 1993). One of the main reasons for using amalgam bonding agents is to reduce or prevent the leakage that has been found even when varnish is used (Varga & others, 1986; Ben-Amar, 1989; Torii & others, 1989; Kawakami & others, 1994).

Overwhelmingly, bonding agents have been found to reduce amalgam leakage, even compared to varnishes such as Copalite (Cooley & Cooley) and Plastodent (Plastodent) (Ben-Amar & others, 1987; Staninec & Holt, 1988; Wetherell & Smales, 1992; Chang & others, 1993; Hadavi & others, 1993; Saiku & others, 1993; Turner, St Germain & Meiers, 1995; Hollis & others, 1996). It is very important to note, however, that the majority of these studies have assessed early leakage (ie, 24-hour or 7-day). Studies that have evaluated the effect on long-term leakage (ie, 6 months, 1-year, 2-year) have been equivocal. Most show a deterioration in the protection against microleakage that is afforded by bonding agents (Cordell, Newman & Berkey, 1991; Moore, Johnson & Kaplan, 1995; Newman & others, 1996). Even long-term, however, bonding agents appear to provide at least as much reduction in leakage as varnishes do. Some studies have demonstrated that the weak link in the amalgam/bonding agent/tooth structure chain occurs between the amalgam and bonding agent (Mahler, Engle & Adey, 1992; Saiku & others, 1993).

Third Claim: Reducing or Preventing Sensitivity

Patients occasionally experience thermal sensitivity following the placement of an amalgam restoration. This is particularly common if a single-composition-spherical alloy is used (eg, Tytin [Kerr], Megalloy [Dentsply/Caulk], Valiant [Ivoclar], Logic+ [SDI]). Proponents of amalgam bonding believe the procedure reduces and, in some cases, actually eliminates the problem. Their rationale is that bonding agents seal dentin tubules effectively which prevents fluid flow from the tubules. According to the hydrodynamic pain theory, fluid flow is the cause of thermally-related pain.

Achieving a consensus regarding the ability of amalgam bonding agents to reduce or prevent sensitivity has been very difficult. The reason is that anecdotal evidence strongly supports the claim (Christensen, 1994a; Christensen, 1994b) while controlled clinical studies show that bonding agents are no more effective than using varnish or nothing at all (Mazer, Leinfelder & Barnette, 1995; Ölmez & Usulu, 1995; Hucke & others, 1996; Mahler & others, 1996; Ruzickova & others, 1996; Browning, Johnson & Gregory, 1997; Kennington & others, 1998; Mahler & Engle, 2000).

Summary of Purported Benefits of Bonding Amalgam

Claim: *Bonds amalgam to tooth structure*

Evidence Indicates: Bonding provides a measureable bond of amalgam to tooth structure

Claim: *Reinforces remaining tooth structure*

Evidence Indicates: Over the short-term, bonding reinforces remaining tooth structure

Claim: *Reduces leakage between amalgam and tooth structure*

Evidence Indicates: Over the short-term, bonding reduces leakage at least as well as, if not better than, traditional varnishes

Claim: *Reduces post-placement sensitivity*

Evidence Indicates: Bonding may, in some cases, reduce post-placement sensitivity

Effect of Bonding Agent on Amalgam s Properties

Laboratory studies have found that some amalgam bonding agents are incorporated into amalgam during condensation (Charlton & others, 1991; Temple-Smithson & others, 1992; Millstein & Naguib, 1995; Mahler & others, 1996; Boston, 1997). Testing has found that the strength of the set amalgam may be adversely affected by this incorporation (Charlton & others, 1991; Millstein & Naguib, 1995). Neither the amalgam s creep rate (Charlton & others, 1991) nor its fracture resistance (Wetherell & Smales, 1992), however, has been found to be affected.

Guidelines when Amalgam Bonding

1. Isolate the treatment area well

-current bonding agents can be applied to "moist" dentin to enhance their resulting bond strength, but this does not mean the dentin can be allowed to be contaminated with blood, saliva, or crevicular fluid. Use of a rubber dam is critically important.

2. Follow manufacturer s instructions carefully

-apply the bonding agent **exactly** as directed in the instructions

3. Select a bonding agent you are comfortable using

-ensure it has understandable instructions for amalgam bonding

-don t rule out using a bonding agent that is strictly VLA; evidence indicates that VLA products are capable of bonding amalgam to tooth structure (Vargas & others, 1994; Winkler & others, 1997; Winkler & others, 2000)

4. Use a minimal amount of agent to prevent incorporating it into the amalgam

-apply a thin layer of the adhesive and keep it from pooling in line angles

Reasons to be Conservative in doing Amalgam Bonding

1. Long-term clinical and laboratory studies are lacking that assess the effectiveness of amalgam bonding agents in retaining amalgam, reinforcing tooth structure, reducing leakage, and reducing sensitivity
2. Use is expensive because:
   --the products are much more costly per application than varnish (Christensen, 1994b; Mahler & others, 1996)
   --the procedure requires more chair time (Christensen 1994b)
3. Bonding is a technique-sensitive procedure, involving multiple steps (Hadavi & others, 1994; Hilton & Schwartz, 1995; Tay & others, 1995; Mahler & others, 1996)
4. Some bonding agents, especially when placed incorrectly, may adversely affect the physical properties of amalgam (Charlton & others, 1991; Millstein & Naguib, 1995)

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